WAsP modelling of 12 stations - method, results and recommendations

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WAsP modelling of 12 stations in Dongbei – method, results and recommendations

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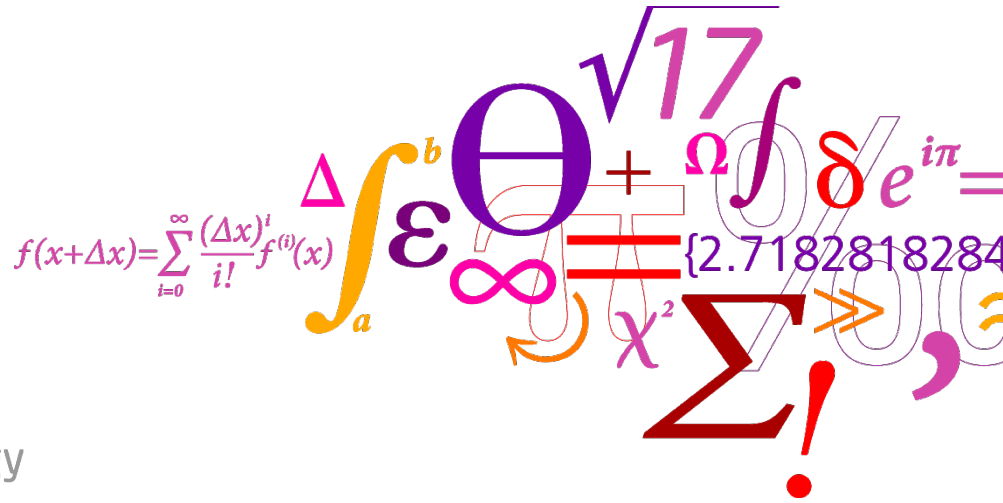
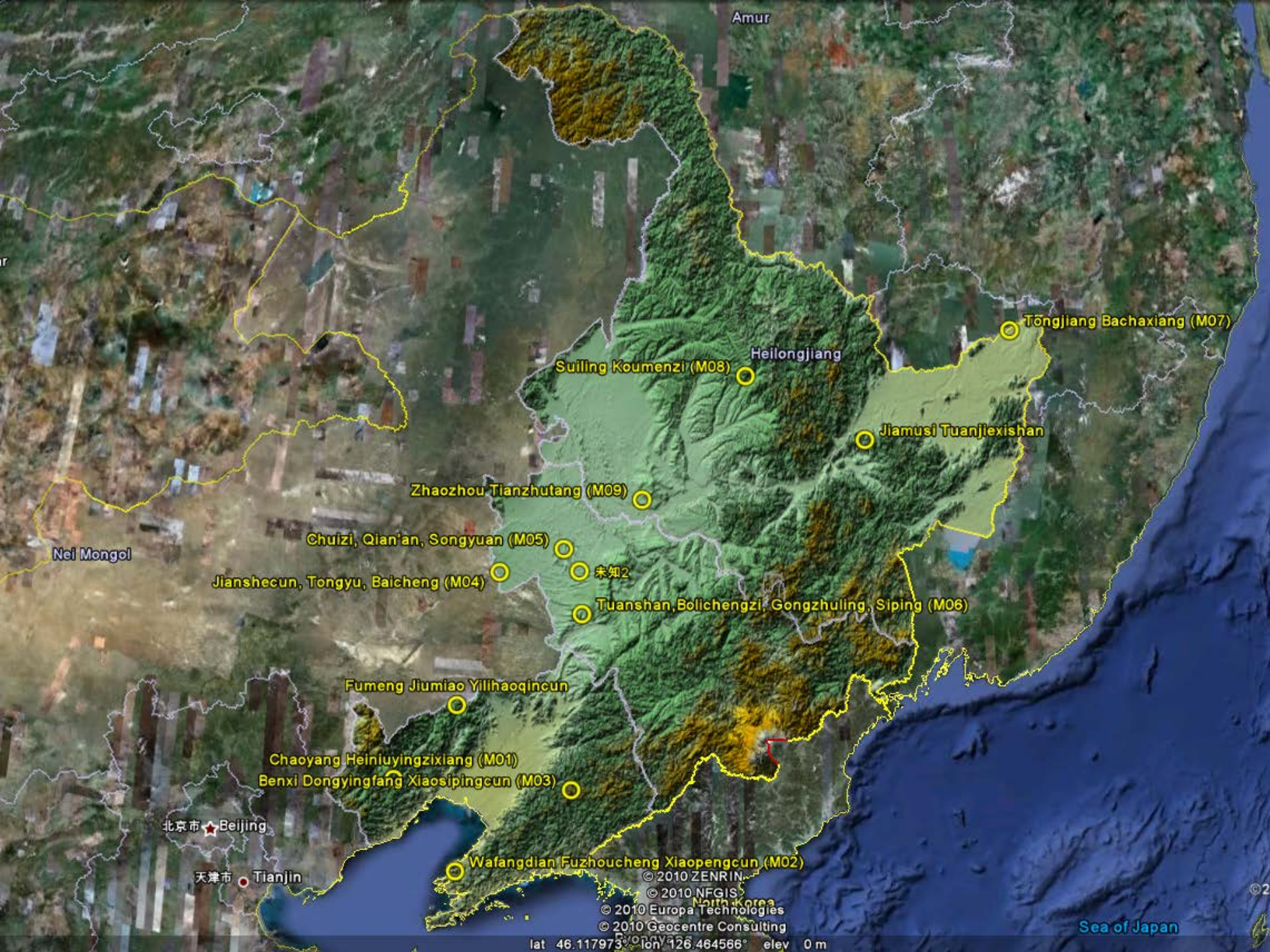


Outline

- Method
  - Microscale modelling of 12 meteorological stations
  - WAsP 10 program and tools employed
  - Observed wind climate from 2009-measurements
  - Topographical maps from space shuttle data and Google Earth
- Results
  - Verification of microscale modelling
  - Sensitivity analysis and uncertainties
- Summary and conclusions
- Recommendations


Amur
Tongjiang Bachaxiang (M07)
Heilongjiang
Suiling Koumenzi (M08)
Jiamusi Tuanjiexishan
Zhaozhou Tianzhutang (M09)
Chuizi, Qian'an, Songyuan (M05)
Nei Mongol
未知2
Jianshecun, Tongyu, Baicheng (M04)
Tuanshan,Bolichengzi, Gongzhuling, Siping (M06)
Fumeng Jiumiao Yilihaoqincun
Chaoyang Heiniuyingzixiang (M01)
Benxi Dongyingfang Xiaosipingcun (M03)
北京市 Beijing
天津市 Tianjin
Wafangdian Fuzhoucheng Xiaopengcun (M02)
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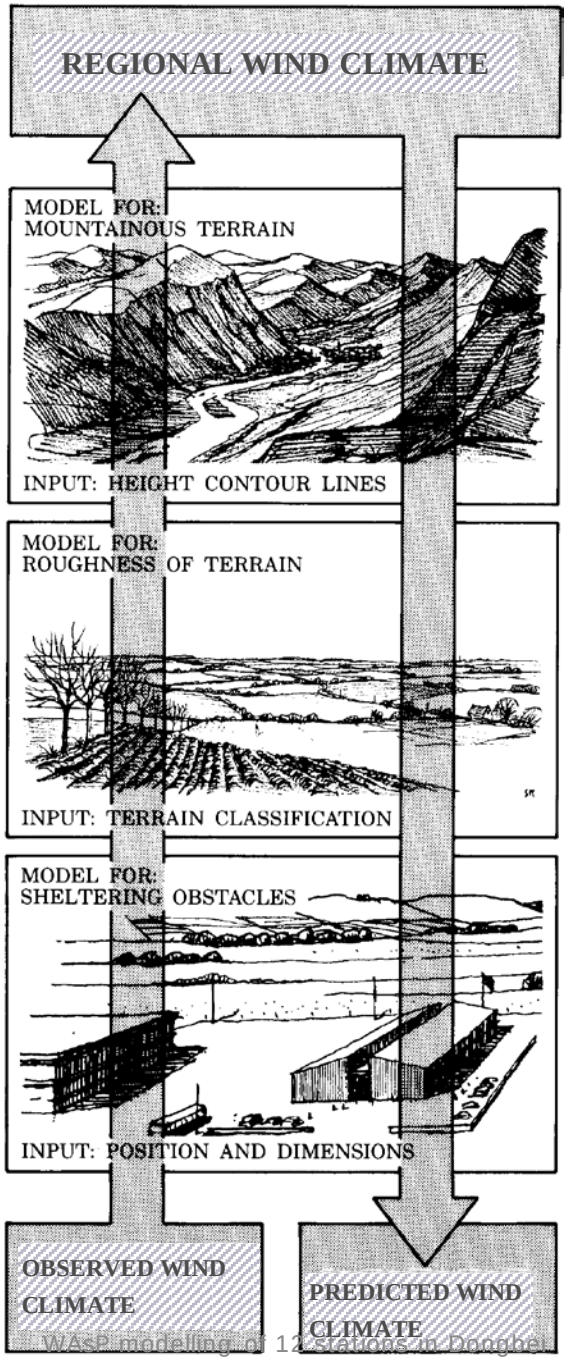
North Korea
Sea of Japan
lat 46.117973° lon 126.464566° elev 0 m

Wind atlas methodology

- Analysis procedure ↑
  Observed Wind Climate
  + sheltering obstacles
  + roughness map
  + elevation map
  ⇒**Regional Wind Climate**

- Application procedure ↓
  Regional Wind Climate
  + sheltering obstacles
  + roughness map
  + elevation map
  ⇒**Predicted Wind Climate**

- Wind turbine and wind farm production
  Predicted Wind Climate
  + power and thrust curves
  + wind farm layout
  ⇒**Predicted wind farm AEP**

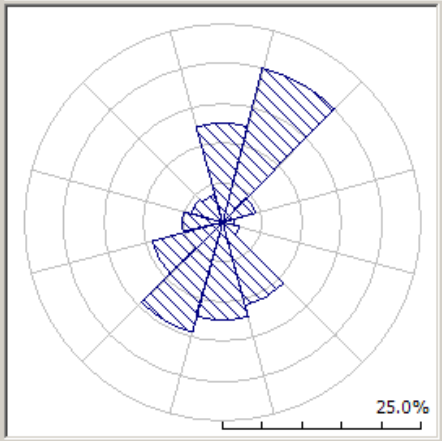


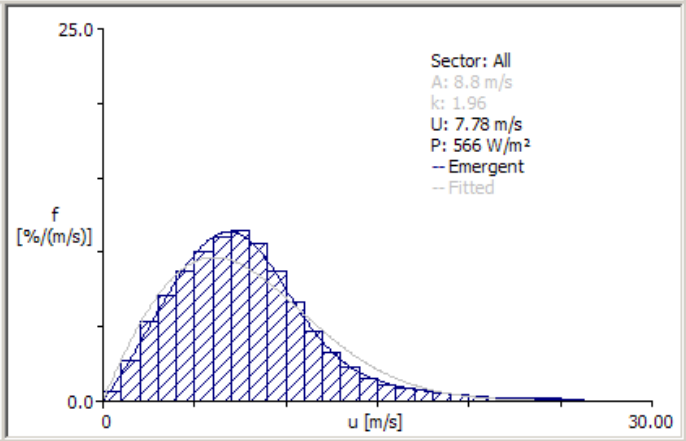
Wind-climatological input (M02)

'Wafangdian Fuzhoucheng Xiaopengcun (M02) at 70.0 m' Observed wind climate

Wind | Histogram bins | Location information | Generation report | Statistics

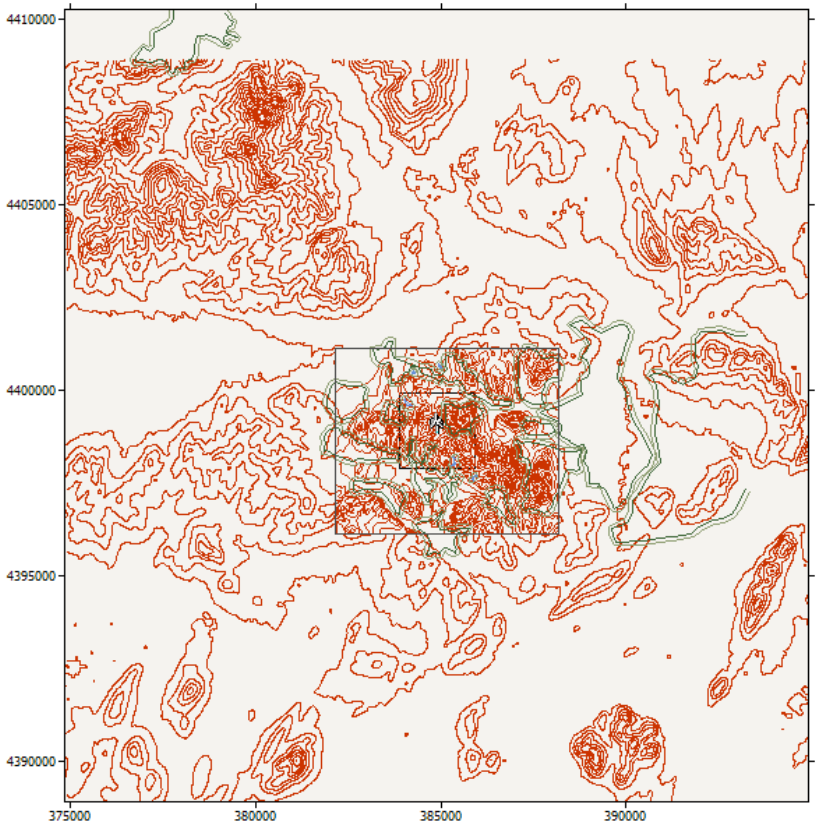
Sector		Wind climate				Power	Quality
number	angle [°]	frequency [%]	Weibull-A [m/s]	Weibull-k	speed [m/s]	power [W/m²]	delta-U [%]
1	0	12.5	10.0	2.22	8.87	750	-0.175%
2	30	20.1	11.2	1.85	9.97	1274	-2.729%
3	60	4.2	5.4	2.03	4.79	128	-0.980%
4	90	1.4	4.3	1.67	3.87	84	-3.166%
5	120	2.3	6.7	2.12	5.91	231	2.993%
6	150	10.8	8.8	3.09	7.91	423	1.133%
7	180	12.3	8.0	3.27	7.14	303	1.146%
8	210	14.3	8.3	3.15	7.40	343	1.155%
9	240	9.1	8.4	2.78	7.52	388	1.280%
10	270	5.1	7.3	2.19	6.48	295	-0.382%
11	300	4.1	6.0	2.12	5.35	172	-0.379%
12	330	3.8	7.5	1.79	6.64	390	-0.528%
All (emergent)					7.78	566	
Source data					7.81	566	



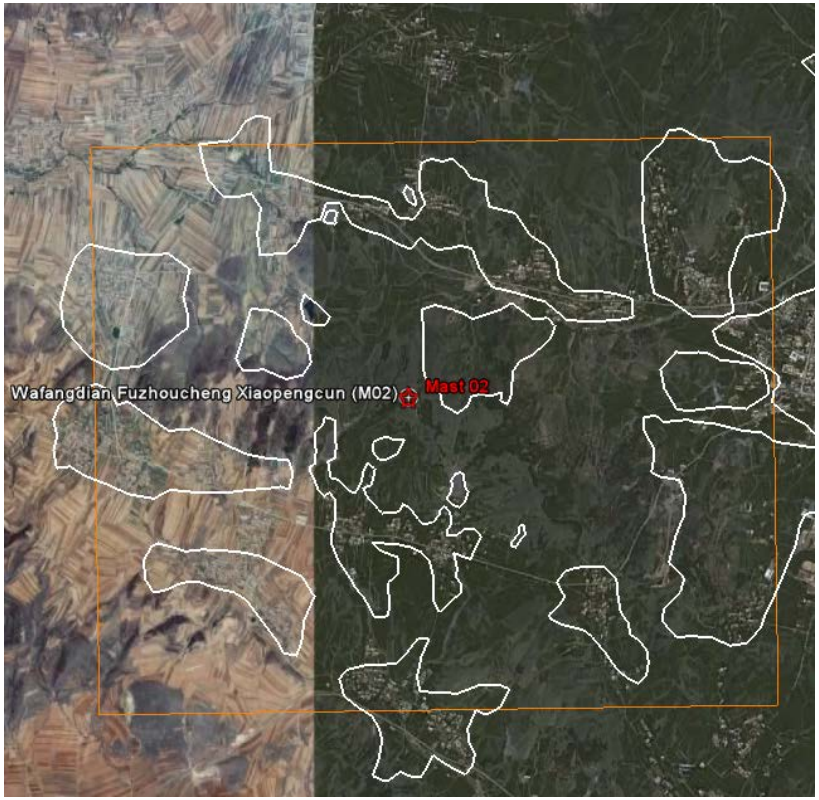


Topographical inputs (M02)

Elevation map from SRTM 3 data set, checked against Chinese paper maps



Land-use and roughness change lines from Google Earth imagery and maps



Results

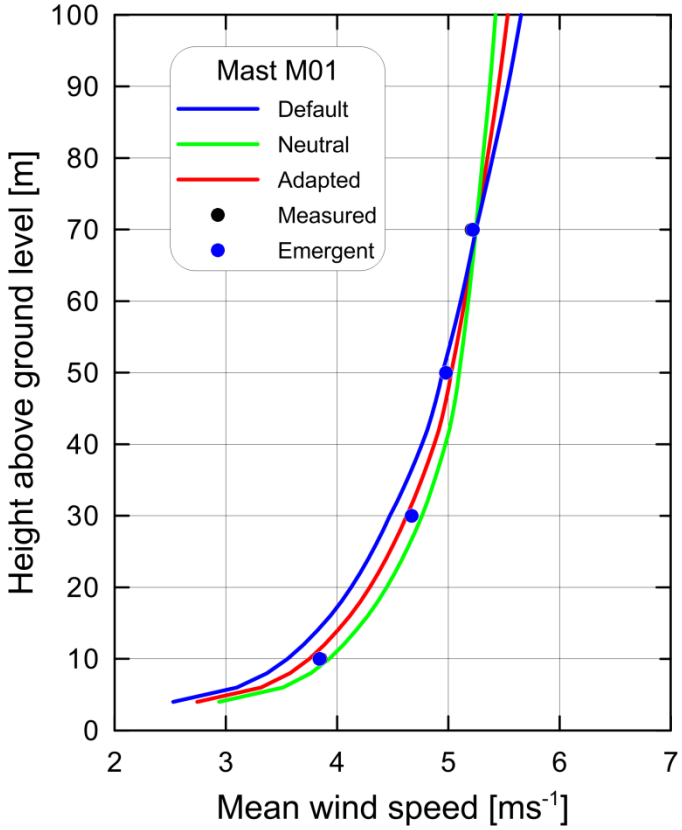
- Verification of microscale modelling
  - Modelling the vertical wind profiles

- Sensitivity analysis and uncertainties
  - How do changes in input data change predictions?
  - How do changes in modelling setup change predictions?

Liaoning sample stations

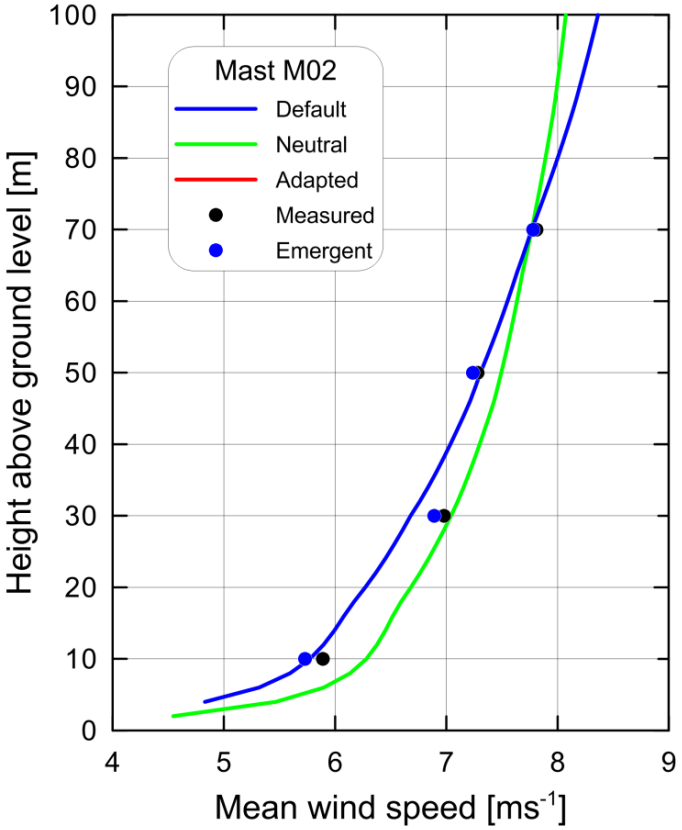
M01 Chaoyang Heiniuyingzixiang

Hilly inland site in SW Liaoning



M02 Wafangdian Fuzhoucheng Xiaopengcun

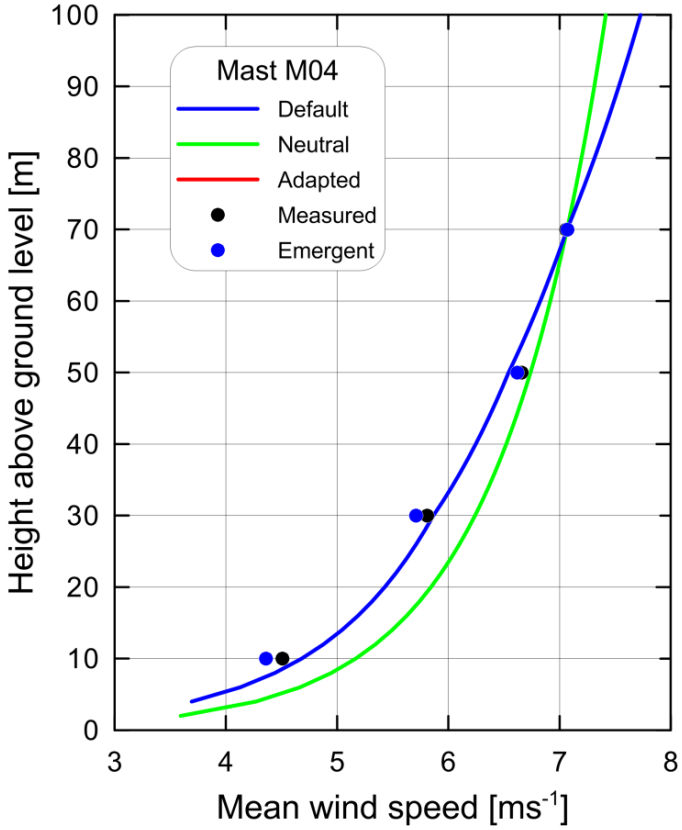
Hilly coastal site in SE Liaoning (case study)



Jilin sample stations

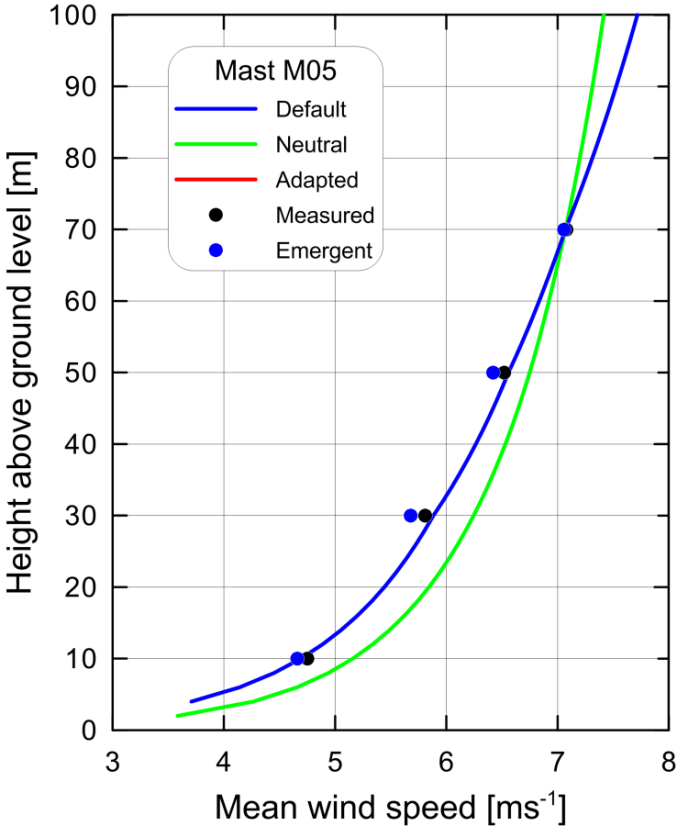
M04 Jianshecun, Tongyu, Baicheng

Flat site in W Jilin



M05 Chuizi, Qian'an, Songyuan

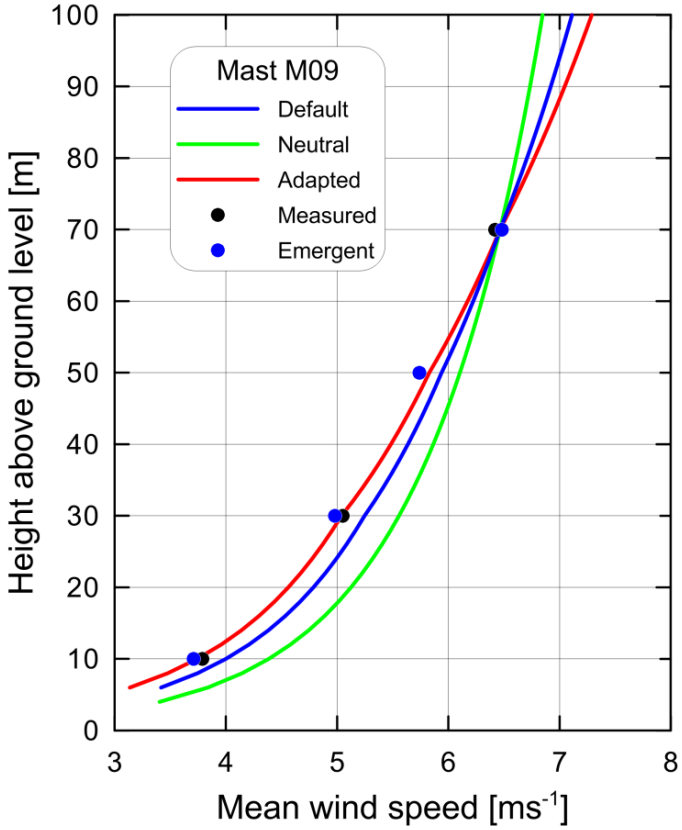
Flat site in W Jilin (case study area)



Heilongjiang sample stations

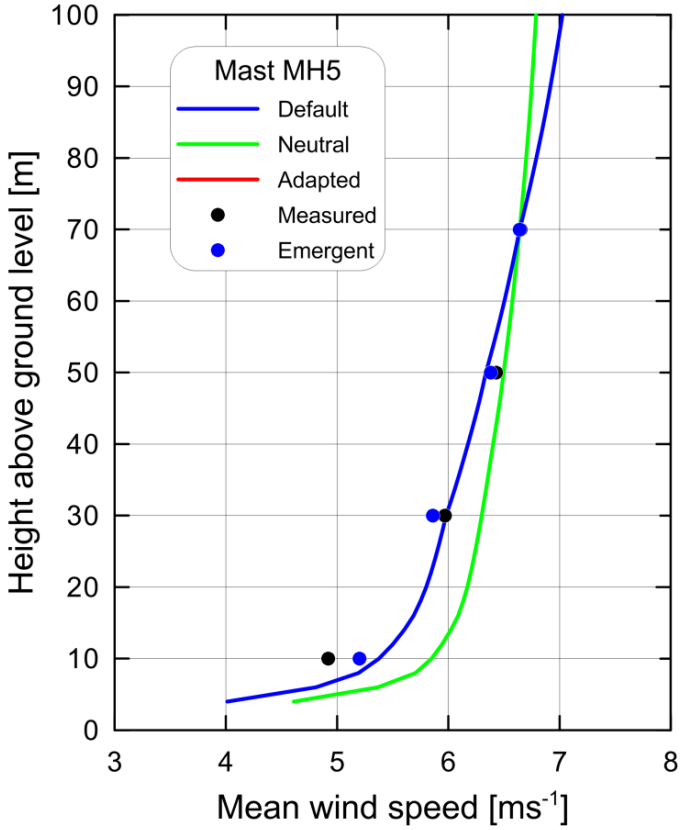
M09 Zhaozhou Tianzhutang

Flat site in S Heilongjiang



MH5 Jiamusi Tuanjiexishan

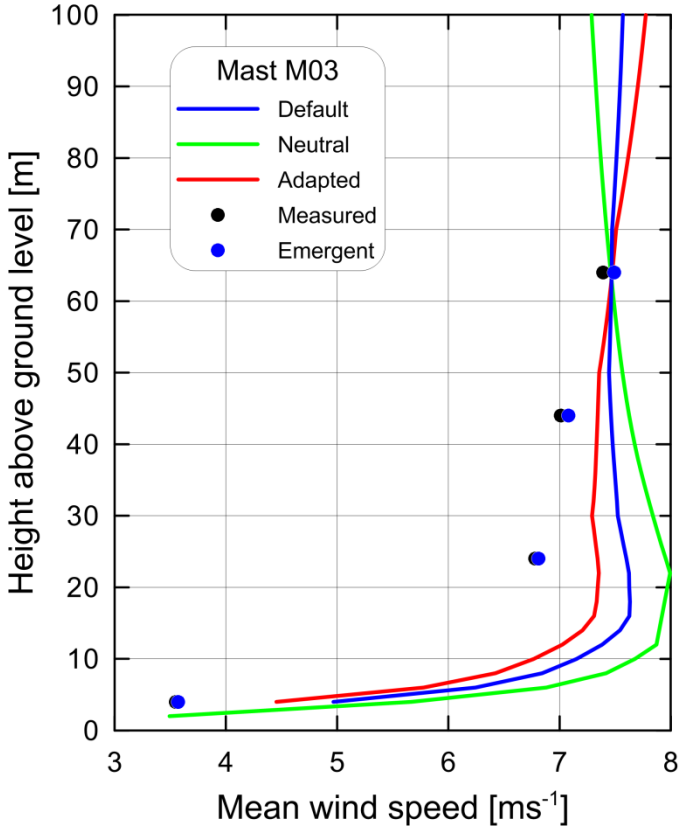
Hilly to complex site (case study area)



Challenging sites!

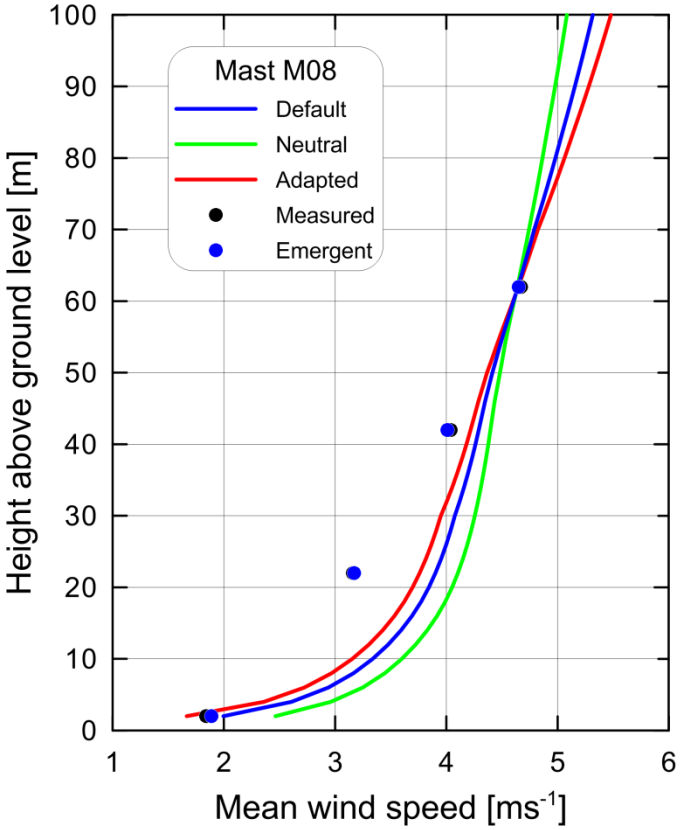
M03 Benxi Dongyingfang Xiaosipingcun

Complex terrain forested site in NW Liaoning

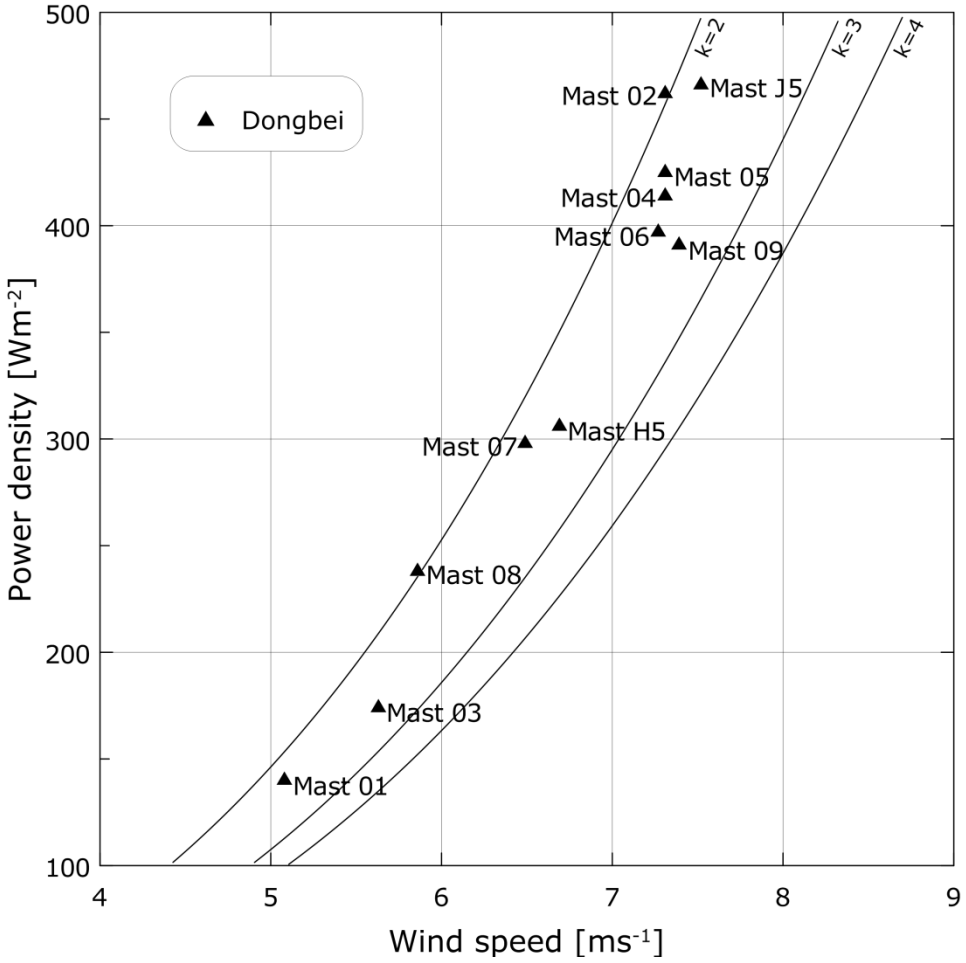


M08 Suiling Koumenzi

Hilly forested site in Heilongjiang



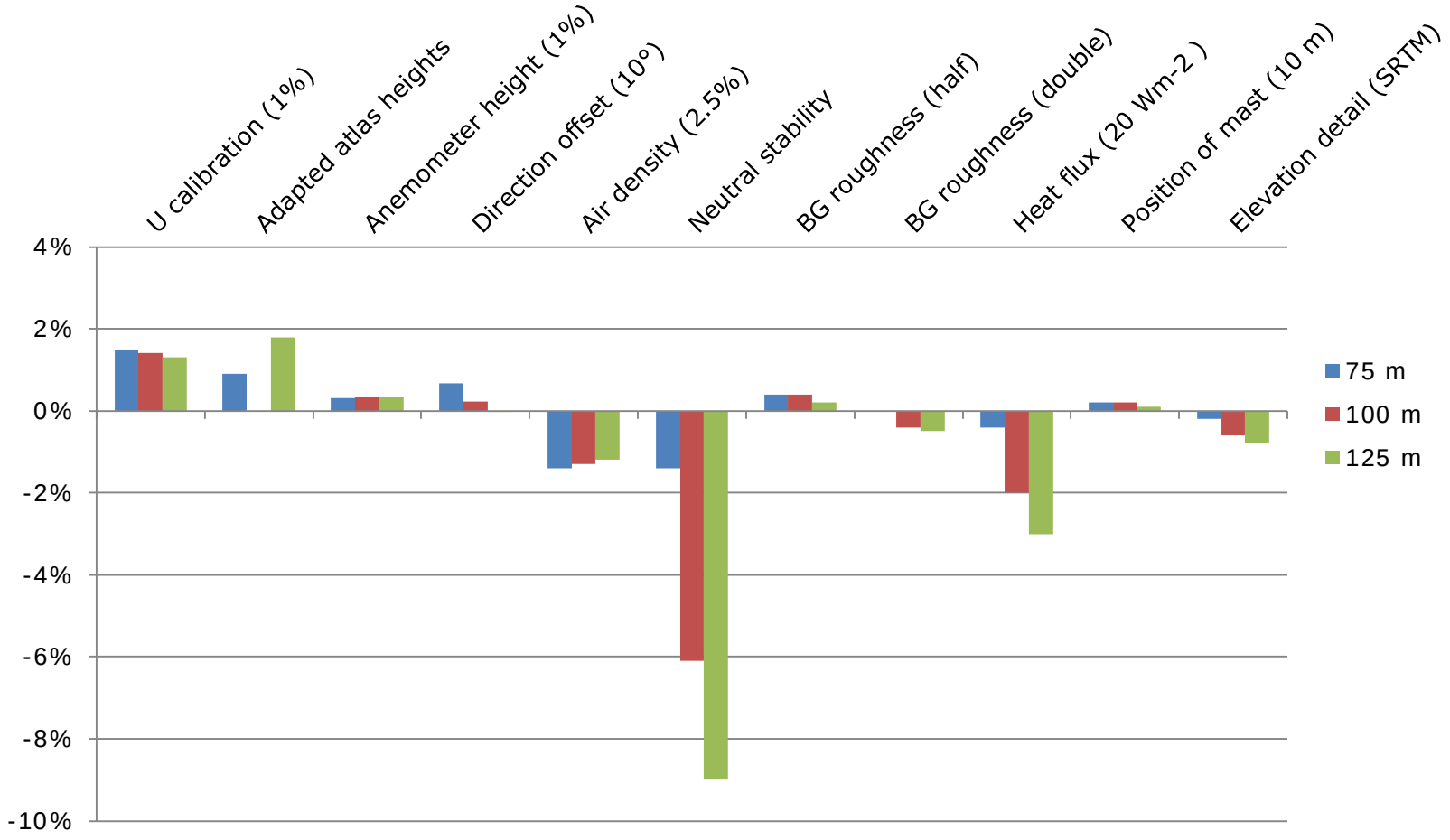
Wind atlas values of *U* and *P* @ 70 m over z_0 = 0.03 m



Sensitivity analyses for 70-m mast M02

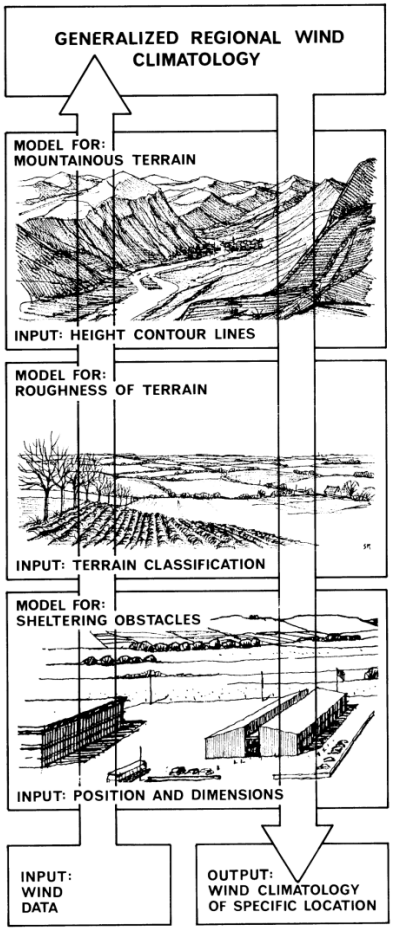
Parameter	Input change	Change in predicted AEP		
		75 m	100 m	125 m
U calibration	+1%	1.5%	1.4%	1.3%
Atlas heights	standard	0.9%	0.0%	1.8%
Anemometer height	-1%	0.3%	0.3%	0.3%
Direction offset	+10°	0.7%	0.2%	0.0%
Air density	-2.4%	-1.4%	-1.3%	-1.2%
Stability	neutral only	-1.4%	-6.1%	-9.0%
BG roughness	half of 5 cm	0.4%	0.4%	0.2%
BG roughness	double of 5 cm	0.0%	-0.4%	-0.5%
Heat flux	+20 Wm^{-2}	-0.4%	-2.0%	-3.0%
Position of mast	±10 m	0.2%	0.2%	0.1%
Elevation detail	SRTM 3 only	-0.2%	-0.6%	-0.8%

Sensitivity analyses for 70-m mast M02



Factors in the uncertainty assessment

- Short-term wind climate
  - measurements
- Long-term wind climate
  - reference data (MCP)
- Wind resource modelling
  - physical models (WAsP, ...)
  - statistical models and fits (Weibull, ...)
- Wind turbine generator data
  - power and thrust curves
  - hub height and rotor diameter
- Wind farm characteristics
  - wind turbine positions (coordinates)
  - wake modelling
  - large-scale effects
- Availability, electrical losses, etc.?
  - simulated, given or estimated
- The human factor...



General Risø experience

- WAsP country and offshore (within operational envelope)
  - AEP = 102%, $\sigma_{AEP} \approx$ **5%** for 20^{+} wind farms
- Complex terrain (outside operational envelope)
  - $|\Delta RIX| < 5\% \Rightarrow$ no improvement by applying ΔRIX
  - $|\Delta RIX| > 5\% \Rightarrow \sigma_u \leq$ **5%** for all x-predictions; typical value 2%
- Numerical wind atlas
  - AEP = 100%, $\sigma_{AEP} \approx$ **10%** for 12 met. masts in 'simple' terrain
  - AEP = 98%, $\sigma_{AEP} \approx$ **20%** for 11 met. masts in 'mountainous' terrain
- Requirements!
  - No gross input or modelling errors
  - Modelling within operational envelopes
  - Measurements according to best practices
  - Microscale modelling according to best practices

Summary and conclusions

- Observational wind atlas for 12 sites in Dongbei has been established
  - WAsP modelling has been verified by comparison to measurements
  - Sensitivity analyses and uncertainty estimation has been studied

- WAsP generally works well in Dongbei!
  - Default modelling parameters work well for most sites
  - Modelling can be improved a bit by specific atlas heights
  - Hilly and steep sites with forest are less well modelled

- Model adaptations in Dongbei
  - Southern sites seem to be slightly more unstable than the default stability settings in WAsP.
  - Northern and mountain sites seem to be slightly more stable than the default settings in WAsP.
  - Requires reliable wind profile measurements and analysis

Recommendations

For every project:

- Follow general *WAsP Best Practices* closely
- Additional recommendations in Component A report
- Compare wind atlas period to nearby long-term data
- Make sensitivity analyses and estimate uncertainties

In general:

- Update observational wind atlas every year!